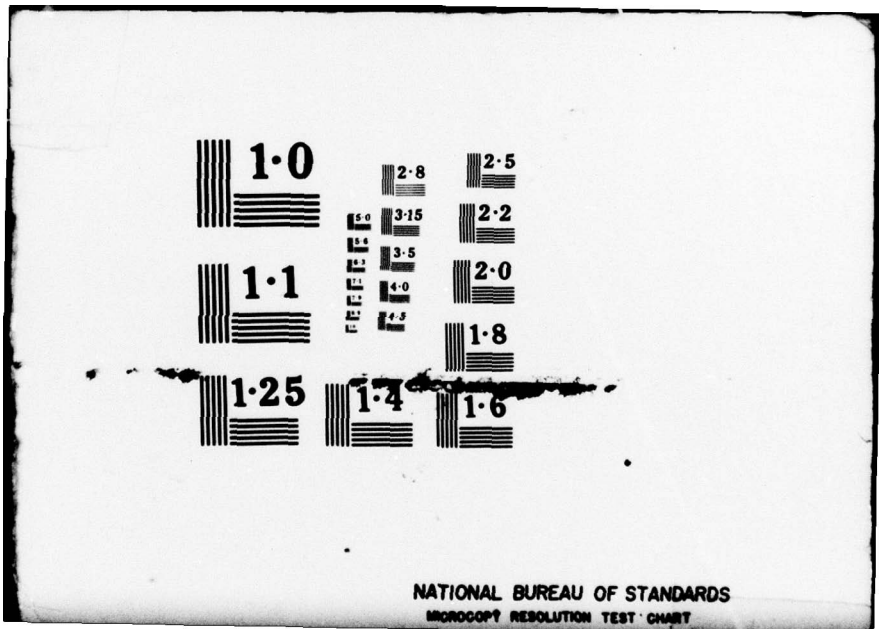
AD-A057 303 NORTH CAROLINA UNIV AT CHAPEL HILL DEPT OF BIOSTATISTICS F/G 12/1
NONPARAMETRIC STATISTICS AND RELIABILITY THEORY.(U)
1978 P K SEN AFOSR-74-2736

UNCLASSIFIED AFOSR-TR-78-1202 NL

| OF |
ADA
057303

END
DATE
FILMED
9-78
DDC


1·0
1·1
1·25
2·8
3·15
3·5
4·0
4·5
1·4
2·5
2·2
2·0
1·8
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

AD A057303

AD No. ____
DDC FILE COPY

(19) REPORT DOCUMENTATION PAGE

(18) 1. REPORT NUMBER AFOSR-TR-78-1202	2. GOVT ACCESSION NO. (2)
4. TITLE (and Subtitle) REPORT ON NONPARAMETRIC STATISTICS AND RELIABILITY THEORY. (6)	5. TYPE OF REPORT & PERIOD COVERED Final
7. AUTHOR(s) (10) Pranab Kumar Sen	8. CONTRACT OR GRANT NUMBER(s) (15) AFOSR-74-2736
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of North Carolina Department of Biostatistics Chapel Hill, NC 27514	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) 61102F 2304 A5 (17)
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Office of Scientific Research/NM Bolling AFB, DC 20332	12. REPORT DATE (11) 1978
	13. NUMBER OF PAGES 6
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) (12) 7p. UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

(9) Final progress rept. 1 Jun 74 - 30 Jun 78,

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DDC RECEIVED AUG 10 1978 F

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During the period (1 June 75 through 30 June 78) under review, the principal investigator ~~has been~~ was mainly interested in the development of various invariance principles for various parametric as well as nonparametric statistics and in their applications to problems in sequential analysis arising in clinical trials and reliability theory. Especial attention ~~has been~~ was paid to the development of nonparametric testing under progressive censoring and their applications. Thirty-nine papers have been published under this grant.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

408 985

FINAL PROGRESS REPORT ON

NONPARAMETRIC STATISTICS AND RELIABILITY THEORY

CONTRACT NO: AFOSR 74-2736(E)

Principal Investigator: Pranab Kumar Sen
Department of Biostatistics
School of Public Health
University of North Carolina
Chapel Hill, NC 27514

During the period (June 1,1974 through June 30, 1978) under review, the principal investigator has been mainly interested in the development of various invariance principles for various parametric as well as nonparametric statistics and in their applications to problems in sequential analysis arising in clinical trials and reliability theory. Especial attention has been paid to the development of nonparametric testing under progressive censoring and their applications.

For various nonparametric statistics relating to the classical one-sample, two-sample and bivariate independence problem and to the problem of randomness against regression alternatives, weak as well as almost sure invariance principles (pertaining to the Wiener process approximations) have been developed in a series of papers. A review of these developments has been presented in Sen (1975). Weak convergence of the Rao-Blackwell estimator of a distribution function has been studied by Bhattacharyya and Sen (1977) (under the condition that the sufficient statistics are transitive). A reverse martingale theorem has been established in this context. Some applications are also considered. Weak convergence of a tail sequence of martingales with especial emphasis on nonparametric statistics has been

Approved for public release;
distribution unlimited.

studied by Sen (1976f). For linear combinations of order statistics, an almost sure invariance principle and a backward weak convergence result are developed in Sen(1977a, 1978a) and the underlying regularity conditions are critically examined.

Progressive censoring schemes are often adopted in clinical trials, reliability and life testing problems with a view to monitoring experimentation from the very beginning for possible early termination of experimentation depending on the cumulating evidence. Along with a basic martingale property, a Wiener process approximation for progressively censored likelihood ratio statistic is established in Sen (1976d) and the same is incorporated in the formulation of some asymptotic sequential tests for the life testing problem. Sen and Tsong (1978a) have looked at the problem from the point of view of progressive truncation and developed invariance principles for progressively truncated likelihood ratio statistics. Progressive censoring schemes are gaining popularity in the area of non-parametric inference too. Sen (1976a) has developed a two-dimensional functional central limit theorem for linear rank statistics. More work in this direction are due to Sen (1976e), Majumdar and Sen (1977, 1978a). Weak convergence of some quantile processes arising in progressive censoring tests has also been studied by Sen (1979a).

Weak convergence as well as almost sure invariance principles for a general class of extrema of sample functions (including the bundle strength of filamemts as a special case) have been studied by Sen (1976b) and Sen and Bhattacharyya (1977). Brownian sheet approximations for partial sums of induced order statistics have been studied by Sen (1976g).

Jack-knifing of regular functions of U-statistics and von Mises' differentiable statistical functions is studied and, in this context, some invariance principles are developed and these are incorporated in the

study of the asymptotic properties of some sequential tests and confidence intervals based on jackknife estimators [Sen (1977b)]. These results are extended to the case of sampling from a finite population by Majumdar and Sen (1978b).

Tied-down Wiener process approximations for aligned rank order statistics are studied in Sen (1977e) with a view to testing (a) a change in location at an unknown point of time and (b) symmetry about an unknown origin. Parallel results for the regression problem are developed in Sen (1978f). A general class of asymptotically distribution-free aligned rank order tests for general multivariate linear models is considered by Sen and Puri (1977).

Preliminary testing on regression parameter before estimating the intercept is a problem of practical interest. Some robust nonparametric procedures are proposed and studied by Saleh and Sen (1978). Recently, Sen (1979c) has extended the theory to the general maximum likelihood estimation case. Almost sure linearity of aligned signed rank statistic (in shift parameter) is studied by Sen (1978c).

Asymptotic normality and invariance principles for the bonus sum and the waiting time in a coupon collector's problem are studied by Sen (1979b) through a martingale approach. The results have important applications in varying probability sampling.

Nonparametric Simultaneous inference procedures for a broad class of Multivariate analysis of variance and covariance models are studied by Sen (1978d) and these unify the existing theory as well.

LIST OF PUBLICATIONS

1. BHATTACHARYYA, B. B. and SEN, P. K. (1977). Weak convergence of the Rao-Blackwell estimator of a distribution function. Ann. Probability 5, 500-510.

2. GARDINER, J.C., and SEN, P. K. (1978). Asymptotic normality of a class of time-sequential statistics and applications. Commun. Statist. Ser. A 373-388.

3. GHOSH, M., and SEN, P. K. (1976). Asymptotic theory of Sequential tests based on linear functions of order statistics. Essays in Statistics of Probability. (60th Birthday volume for Prof. J. Ogawa). (Ed. S. Ikeda). pp. 480-499.

4. GHOSH, M., and SEN, P. K. (1977). Sequential rank tests for regression. Sankhya, ser. A. 39, 45-62.

5. MAJUMDAR, H., and SEN, P. K. (1977). Nonparametric tests for multiple regression under progressive censoring. Commun. Statist. Ser. A, 6, 507-524.

6. MAJUMDAR, H., and SEN, P. K. (1977). Nonparametric testing for multiple regression under progressive censoring. Jour. Multivar. Anal. 8, 73-95.

7. MAJUMDAR, H., and SEN, P. K. (1978b). Invariance principles for jackknifing U-statistics for finite population sampling and some applications. Commun. Statist. Ser. A., to appear.

8. NEUHAUS, G. and SEN, P. K. (1977). Weak convergence of tail-sequence processes for sample distributions and averages. Mitteilungen aues dem Mathematisches Seminar Giessen 123, 25-35.

9. SALEH, A. K. Md., and SEN, P. K. (1978). Nonparametric estimation of location parameter after a preliminary test on regression. Ann. Statist., 6. 154-168.

10. SEN, P.K. (1975). Rank statistics, martingales and limit theorems. In Statistical Inference and Related Topics. (Ed. M. L. Puri). Academic Press, New York. pp. 129-158.

11. SEN, P. K. (1976a). A two-dimensional functional permutational central limit theorem for linear rank statistics. Ann. Probability. 4, 13-26.

12. SEN, P. K. (1976b). An almost sure invariance principle for the extrema of certain sample functions. Ann. Probability 4, 81-89.

13. SEN, P. K. (1976c). A note on invariance principles for induced order statistics. Ann. Probability 4, 676-679.

14. SEN, P. K. (1976d). Weak convergence of progressively censored likelihood ratio statistics and its role in asymptotic theory of life testing. Ann. statist. 4, 1247-1257.

15. SEN, P. K. (1976e). Asymptotically optimal rank order tests for progressive censoring. Calcutta Statist. Assoc. Bull. 25, 65-78.

16. SEN, P. K. (1976f). Weak convergence of a tail sequence of martingales. Sankhya, Ser. A. 38, 190-193.

17. SEN, P. K. (1976g). A note on invariance principles for induced order statistics. Ann. Probability 4, 474-479.

18. SEN, P. K. (1977a). Embedding of Wiener processes for linear combinations of order statistics. Sankhya, Ser. A. 39 138-143.

19. SEN, P. K. (1977b). Some invariance principles relating to Jackknifing and their role in sequential analysis. Ann. Statist. 5, 316-329.

20. SEN, P. K. (1977c). Almost sure convergence of generalized U-statistics. Ann. Probability. 5, 287-290.

21. SEN, P. K. (1977d). Rank analysis of covariance under progressive censoring. Institute of Statistics, Univ. of North Carolina, Mimeo Report No. 1118.

22. SEN, P.K. (1977e). Tied-down Wiener process approximations for aligned rank order processes and some applications. Ann. Statist. 5, 1107-1123.

23. SEN, P. K. (1977f). On jack-knifing in estimating the finite end-points of a distribution. Calcutta Statist. Assoc. Bull. (in press).

24. SEN, P. K. (1978a). An invariance principle for linear combination of order statistics. Zeit. Warsch. Vera. Geb. 42, 327-340.

25. SEN, P. K. (1978b). Invariance principles for rank-discounted partial sums and averages. Zeitschrift fur Warsch Vera Geb. 42, 341-352.

26. SEN, P. K. (1978c). Invariance principles for linear rank statistics revisited. Sankhya, Ser. A. 40, in press.

27. SEN, P. K. (1978d). Nonparametric simultaneous tests for some MANOVA models. (to be published).

28. SEN, P. K. (1978e). On almost sure linearity theorems for signed rank statistics. (to be published).

29. SEN, P. K. (1978f). Asymptotic theory of some tests for a possible change in the regression slope occurring at an unknown time-point. (to be published).

30. SEN, P. K.(1978g). The extended two-sample problem: nonparametric case. (to be published).

31. SEN, P. K. (1979a). Weak convergence of some quantile processes arising in progressively censored tests. Ann. Statist. 8, in press.

32. SEN, P. K. (1979b). Invariance principles for the coupon collector's problem: A martingale approach. Ann. Statist. 8, in press.

33. SEN, P. K. (1979c). Asymptotic properties of maximum likelihood estimators based on conditional specifications. Ann. Statist. 8, in press.

34. SEN, P. K. and BHATTACHARYYA, B. B. (1976). Asymptotic normality of the extrema of certain sample functions. Zeit. Warsch Vera. Geb. 34, 113-118.

35. SEN, P. K. and GHOSH, B. K. (1976). Comparison of some bounds in estimation theory. Ann. Statist. 4, 755-765.

36. SEN, P. K. and PURI, M. L. (1977). Asymptotically distribution-free aligned rank order tests for composite hypotheses for general multivariate linear models. Zeit. fur Wahrsch Vera Geb. 39, 175-186.

37. SEN, P. K. and SALEH, A. K. Md.E. (1977). Nonparametric estimation of location after a preliminary test on regression in the multivariate case. (submitted for publication).

38. SEN, P. K. and TSONG, Y. (1978a). An invariance principle for progressively truncated likelihood ratio statistics. (submitted for publication).

39. SEN, P. K. and TSONG, Y. (1978b). On functional central limit theorems for certain continuous time parameter processes. (submitted for publication).